"At the time ARPAnet was conceived, computers, programs and communication lines were really costly.
The main objective behind the development then, was to share[1] expensive resources in a robust and efficient manner between geographically distributed users"

Pål Spilling The European TCP/IP pioneer.

Interviewed on July 28th, 2005 at Stanford (CA) & Oslo (Norway)

Born in October 29th 1934, in Harstad, Norway.

He received his cand.real.[2] degree in physics at the University of Oslo in March 1963, and his Ph.D. in experimental nuclear physics from University of Utrecht, the Netherlands in July 1968.

He is a professor with the University of Oslo, assigned to UniK – University Graduate Center at Kjeller, Norway. He has regularly given graduate and undergraduate courses in Computer Communication and security, from 1985 until 2006, focusing his actual research on security and wireless communications.

paal@unik.no

1963 - 1971; nuclear physics research; universities of Utrecht and Eindhoven.
1972 - 1982; Norwegian Defense Research Establishment NDRE Internet research.

From end 1974 he got involved with the ARPA-funded research program in packet switching and internet technology under the leadership of **Yngvar Lundh**. He was visiting scientist with SRI International in 1979-80 in Menlo Park, California, where he worked on the Packet Radio program. Spilling left NDRE in August 1982 to join the Research Department of the Norwegian Telecommunications Administration (NTA-RD), also at Kjeller.

---

1 A good example is the following: I was participating in speech experiments across the ARPAnet around 1978, and had to modify a voice applications program for our PDP-11/40, located next door to my office at the Norwegian Defense Research Establishment (NDRE). All programming support was hosted at a computer at ISI just north of Los Angeles. The access to these resources went via my terminal connected to NORSAR-TIP and the Telnet program. I could then use a text editor for the modification of the existing program, and then assembling and linking the modified program then using the XNET debugger to upload the program across the network and into the PDP-11/40, and then use the debugging facilities in the XNET to step through the program instruction for instruction, to observe that all was correct. Then came the internet, personal workstations, later Lap-Tops, and then the Web, and the network was transformed into sharing of a global information base.

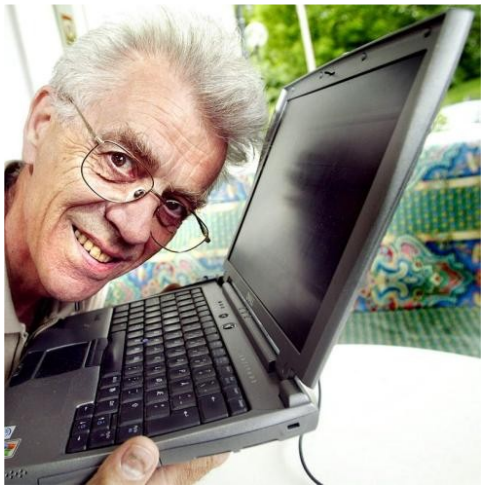
2 cand.real. is an older version of the master degree.

Subsequently he established the first internet node outside USA, interconnected with the US internet.

1982 – 1993; R&D Dept. Telenor; Internet research and fiber communications.
1993 – 2005; Oslo Univ. Professor of Communication networks, security,
and mobile communications.

Do you remember when you had your first contact with a computer?
I had my first real contact with a computer in 1964, when I had to process data from nuclear physics experiments recorded on large rolls of paper tapes. At that time I was working on my PhD research performed at the Dutch nuclear reactor in Petten. The computer was also Dutch, and the program was written by software experts at the Dutch Reactor Centrum.

Some years later I worked with the University of Technology in Eindhoven (Netherlands), also doing experimental research in nuclear physics. I had just received a FORTRAN program, on IBM punch-cards, to help me process and analyze my experimental results, but did not find the output too suitable for my purpose. I then proceeded to modify the output part, which was my first contact with FORTRAN programming. For an experienced programmer this was certainly a trivial task, but not for me. So I was very proud of myself when I had the modifications fixed and running as I wanted.



Picture by: Lisbeth Andersen

What was your first contact/experience with ARPAnet?
Working with the Norwegian Defense Establishment (NDRE), I was asked in 1975 to participate in the newly established collaboration between NDRE and the American DARPA[3]. I said yes, but did not realize fully what I was doing, considering my background in electronics and nuclear physics. My first task was to participate in a meeting in professor Cerf's group at Stanford University in 1975/76. With my background I did not get much out of the meeting, except that they were discussing details of the TCP protocol.

[3] ARPA: Advanced Research Project Agency. Organization whom started and sponsored the ARPAnet.

My first contact with the ARPAnet was around the same time. NDRE had agreed to participate in the SATnet project, and in this connection I was put in charge of getting a Norwegian-built computer, located at NDRE, hooked up to the ARPA-node at Kjeller (NORSAR-TIP). Due to the distance to the TIP, we had to use the 1822 VDH interface. I got the interface specifications from BBN in Boston and had a technician at NDRE to build the hardware interface. To my disposition I had a naked computer without any form for operating system, and an assembler, a linker, and a loader program. It was obvious that I first had to develop a multitasking system for the computer and then the driver for the 1822 interface. I was very lucky to get hold of a SRI report by Dave Retz describing the ELF operation system for PDP-11/45. It gave me sufficient understanding of what a multitasking system should do, so that I could proceed to implement my own. After quite a bit of work and frustrations, I hooked up the computer to NORSAR-TIP – to great satisfaction for myself.

In your opinion, what are the key characteristics of Internet?

- The internet technology can utilize any underlying network transport technology. This means that any network should be able to connect to any other network without requiring internal modifications
- The packet transport in the network is connectionless. It utilizes adaptive routing, hence the network will be very robust with respect to failures
- No central management and control.
- The network is open, meaning that the host computers are always on, with the consequence that the hosts are prone to illegal access and hacker attacks.
- User security is not directly part of the network, but handled outside the network domain. But all security support functionality is directly accessible from the internet, hence vulnerable and prone to hacking
- So as a summary we can say that it is a network of networks, IP tie everything together and is irrelevant what is underneath.

What do you consider the most important milestones in the development of the network?

- The implementation of the ARPAnet and the host-to-host communications in the timeframe 1969 till 1972 (including the development of e-mail, FTP & Telnet).

- The TCP testing performed in October 1975 between Stanford University and University College of London.

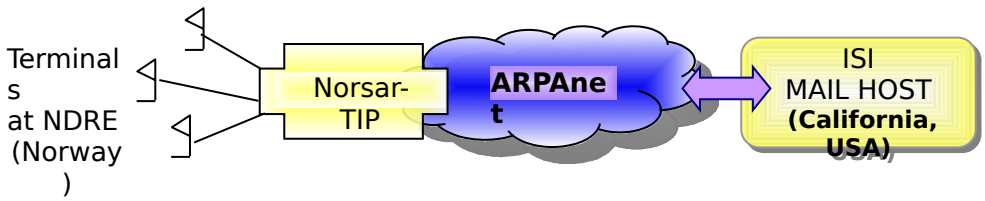
- Two – network demonstration in August 1976 at SRI, between a PRnet[4] host and an ARPAnet host, and the multi-network demonstration performed in November 1977 involving SATnet, ARPAnet, and PRnet.

- The ARPAnet – Internet went through three distinct phases:
  - The basic research and development phase sponsored and supervised by ARPA; The ARPANET – Internet was a closed group from its inception in 1968/69 until 1983 when all ARPANET host converted to the TCP/IP suite of protocols. All participating institutions had to be accepted by ARPA.

  - An interim phase; the network was split in two parts. One part, called MILNET, contained all defense institutions. The other part, still called ARPANET, was open to research institutions in general, not only in the US but also in Europe. At the end of the decennium, NSF[5] had taken over the responsibility for the main part of the US – network, and with interconnections to networks in Europe and other continents. Many of the regional networks were privatized.

  - The World Wide Web was invented at CERN in 1989, and the first commercial browser was available in 1993. At the same time the restriction on commercial use of the network was lifted, and was the start of the third phase. This resulted in an explosive growth of the internet, when private organizations were allowed to interconnect their own networks.

- From a Norwegian perspective, and important date was June 1973 when the ARPAnet-node NORSAR-TIP was installed at the computing center at Kjeller Norway. It was connected, via a land line to the Nordic satellite ground station at Tanum Sweden and from there over the satellite, to the US part of ARPAnet. NDRE had a set of terminals connected to NORSAR-TIP. Via such a terminal and the Telnet client part in the TIP, I could get to my mail host[6] at ISI in California.



- At that time it was very expensive to have a computer or to have the appropriate software. The main philosophy and an

[4] PRNET: Packet Radio Network. Network using the "packet switching" paradigm through hertzian radio links.
[5] NSF: National Science Foundation.
[6] The ISI mail host, was a Digital (DEC) machine: PDP-11/45.

important goal for the ARPAnet were to make things more affordable by sharing resource.

How did you contribute to the development of the Internet?
As mentioned previously, I implemented the first Norwegian host on ARPANET. Via my primitive host at NDRE, connected to the NORSAR-TIP, I could control the satellite nodes (SIMP[7]s) to generate artificial traffic in SATnet, collect traffic measurement data, and have those shipped to my host at NDRE for off-line processing. The objective of the SATnet project was to study access control algorithms, in order to devise a suitable one for both normal datagram traffic and traffic with real-time properties (voice). A colleague of mine[8] at NDRE and I participated extensively in these activities, contributing both theoretically and experimentally, to establish the foundations for the SATnet.

Having a proper access control algorithm in place, SATnet was used as an autonomous network interconnecting local area networks, at NDRE and University College of London, with ARPANET, and proved to be a very suitable arena for developing and refining the internet gateway technology. NDRE was mainly an observer to these activities.

At the end of the SATnet project, 1978-79, I participated in extensive packet speech experiments and demonstrations mainly involving Lincoln Lab (at MIT Boston, MA, USA), UCL (UK), and NDRE (Norway). My task there was to study the profile of packet speech traffic in the network. The programming to be done in this context was, as previously mentioned, a good example of resource sharing – the original paradigm the ARPANET built on.

After the SATnet project came to an end in 1979/80, it was put into experimental operations to interconnect local area networks (LANs) at NDRE and UCL with ARPANET. In 1982 I moved over to Telenor R&D, also at Kjeller, and continued the collaboration with the DARPA community from this location. Moving to Telenor R&D enabled me to create a small Norwegian internet, interconnecting LANs located at the universities in Oslo, Trondheim and Bergen, and at NTA-R&D, and from there via SATnet to hosts at UCL and attached to ARPAnet.

[7] SIMP: Stands for Satellital IMP. A special Interface Message Processor.
[8] **Finn Arve Aagesen**, later a professor in telematics at the university in Trondheim Norway.

Pål during a summit at Stanford July 28th 2005. In the background can be seen other ARPAnet and Ethernet pioneers: Left to right. Yogen Dalal, Bob Metcalfe and Dave Boggs.

In most European countries, the standardization effort focused mainly on connection-oriented transport in the network. This was heavily influenced by the line-mode of operation by the European national telecom monopolies, and was initially the foundation of the OSI[9] protocols.

The telecom operators and the standardization bodies didn't believe in TCP/IP. This had the implication that I sort-of was living 10 years ahead of colleagues at both NDRE and NTA-R&D. I was unable to inspire them to join me in the collaboration with the DARPA community, and had to work more or less alone for many years.

Whom do you consider to be the key people in the development of Internet – leaders or trendsetters?

The development of computer networks was in many ways inspired by **JCR Licklider**'s vision presented in his seminal paper "Man – Computer Symbiosis" from March 1960. Independently of one another, **Paul Baran**, then at Rand Corporation, **Len Kleinrock** at UCLA, and **Donald Davies** at NPL in England, in the 1960s, studied different aspects of message/packet switching. In 1965 **Larry Roberts**, then at Lincoln Lab, was awarded funding from DARPA for an experimental project developing the functionality to exchange digital information over a dial-up phone line between a computer at

[9] OSI: Open Systems Interconnection. It was a Standard from ISO, promoted by telecom companies, governments, and competing with the TCP/IP until 1992.

Lincoln Lab and a computer at SDC in Santa Monica. Shortly after he had demonstrated this capability in 1966, he was asked to join the IPTO office at DARPA to lead the new project to develop a wide area digital communications network, that later was named ARPAnet.

After having managed the project and seen a reasonable mature ARPAnet in operation, interconnecting hosts distributed across the American continent, Larry Roberts left DARPA in 1973 to become President of Telenet. Telenet was providing commercial data communication services based on the X.25 standard. This is kind of strange. The X.25 standard is based on connection-oriented transmission in the network, promoted very strongly by the standardizations community, while the emerging technology in the DARPA community and the soon-to-be foundation for the internet technology was based on the datagram paradigm. These two communities were strongly opposed to one another, like cats and dogs. Did this imply that Larry Roberts at that time did not believe in the datagram concept?

Robert Kahn, with experience from BBN in designing and specifying the ARPAnet IMPs, joined the IPTO office in 1972, and later became its director. In 1973 he and **Vint Cerf**, then an assistant professor at Stanford, conceived the main principles the internet should build on, and published this in May 1974. These two people were the driving force behind the internet development.

But there are numerous other people that have contributed to this development, all in a giant symphony conducted by Bob Kahn and Vint Cerf. May be I should mention one person that has had an enormous impact on the usability of the internet, namely **Tim Berners-Lee** and his invention of the Web.

Regarding Europe, I would like to mention Professor **Peter Kirstein** of UCL in London. He was the key person to promote the use of the internet technology in Europe – first in England and then in Europe.

I would also like to mention **Petter Kongshaug**. He understood early in the 1980s the advantageous of the internet technology and was promoting its use in Norway. He sort of took over my initial small Norwegian internet in mid 1980s and created the UNINETT organization that after a while interconnected all universities in Norway. He was also a key person in creating NORDUNET, a network that interconnected all academic networks in Scandinavia. NORDUNET was also interconnected with the emerging European networks and with the NSFnet in the US.

Two anecdotal situations

Landing in Los Angeles in 1977 to attend an ARPA-meeting somewhere in California, and discovering that I had forgotten to bring with me the meeting information. Luckily I found my way to ISI where a friendly PhD-student let me in and gave me access to a terminal, so that I could read my mail and get the meeting information. By the way, ISI was at that time hosting my email account.

Around November the 1st 1983 **Ronald Mark Austin**, a 19-years old student at UCLA, was arrested and charged with illegal access to and theft from a large number of computer systems connected to the ARPAnet. Among those were several systems belonging to the American defense. It was also believed that Austin had broken into the main campus system at Kjeller Norway, which served both the Norwegian Defense Research Establishment (NDRE), The Norwegian Air Force base at Kjeller, and Oslo University, according to one of the Norwegian newspapers – blowing up the story in large headlines. It turned out to be my VAX-750 that was invaded, used for my collaboration with the ARPA community, and contained neither defense secrets nor other sensitive material. I had a hard time responding to all phone calls received from national security people, the research institutes at Kjeller, the Defense Security Agency, and lots of newspapers. In addition I received a subpoena from the Court in Los Angeles. When they learned about the real situation, the subpoena was of course cancelled.

What do you think about the future of Internet?

The internet will increasingly encapsulate the whole world, gradually converting it into the so-called global village. It will enable people from different cultures to access the same global information base, provide them with an easy way to communicate and exchange views, and thereby hopefully reduce the tensions between the people/cultures of the global village and enable peaceful coexistence.

The internet is penetrating into all aspects of our society, making the mankind increasingly dependent on the reliable and secure operations of the network and its services. This is a scary situation, since adequate quality, reliability, and robustness against failures and hacking of our networks and information systems are not yet in place.

The future of the internet is something you can hardly imagine. One example I often mention is as follows: the always-on principle and cheap communication facilities, will enable old-aged or handicapped people to stay in-touch with family, friends, and the society at large, at any time and irrespective of where people are located, using for example voice conference facilities adapted to the type of handicap and user needs.

Do you see any important or interesting technological trends?
The internet is mostly based on fiber-optical transmission networks, where the capacity of the transmission network is steadily being increased by refining the DWDM[10] technique.

Going back to the mid 1970s and the harsh struggle between the standardization and the DARPA communities, the two communication directions (virtual lines and datagram), both had their advantageous and disadvantageous. DARPA at that time was strongly advocating against virtual lines. It is therefore interesting to observe the effort, in the last decade or so, to integrate the advantageous of virtual lines into the internet without compromising the datagram concept. I refer here on the introduction of Multi-Protocol-Label-Switching (MPLS) and queue controls in the routers, in order to fulfill real-time and other quality of service transmission issues.

The internet users are steadily being more mobile, wanting to use internet service – including voice calls – from anywhere and at any time. We will see the development of more suitable PDAs, with expanded capacity and lower power consumption, combining phone, voice conferencing, and normal internet services. Such devices will not only be used to access the internet, but will increasingly be used

for mobile-to-mobile communications.

Pål Spilling with the author during the first interview at Stanford –CA-

[10] DWDM: Stands for Dense Wave Division Multiplexing. A way to increase the amount of information transmitted through a communications channel.

Computing elements will increasingly be embedded in things like airplanes, cars, home appliances, in farming, in the industry, in the medical world, in other words be part of the personal, commercial, and public domains. That means we will be more and more dependent on the reliable functioning of such electronic elements containing more or less reliable software. We are not that far yet, and will see an increased focus on methods and tools for the development of robust and reliable software.

ADDITIONAL READING

PAPERS & BOOKS MENTIONED / RECOMMENDED

Pål Spilling & Yngvar Lundh 2004. *"Features of the Internet history The Norwegian contribution to the development"* Telektronikk March 2004. Pages 113 to 133. (20 pages)